Differences in weight and habit of Whooper *Cygnus cygnus cygnus* and Mute *C. olor* Swans in relation to differences in their long bones

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Whooper Swans *Cygnus cygnus cygnus* are smaller and more terrestrial in their habits than Mute Swans *C. olor,* and, in addition, the former are migratory whereas the latter fly only short distances (Cramp & Simmons 1977). Differences in the long bones may be related to these differences in weight and habit.

Whooper Swans have longer legs than Mute Swans (Table 1), (comparing femur and tarsometatarsus lengths $P<0.005$) but their toes are shorter in

TABLE 1

Ranges in length and width, with means and standard deviations (all in mm), of long bones of Whooper Swans *Cygnus cygnus cygnus* and Mute Swans *C. olor*.

	Whooper Swan			Mute Swan		
	Range (n)		Mean ± s.d.	Range (n)		Mean ± s.d.
Humerus						
Length	256–300	(28)	275.5 ± 12.18	270–311	(33)	290.9 ± 14.05
Width	10.4–13.8		12.30 ± 0.96	10.8–13.7		12.29 ± 0.88
Ulna						
Length	242–277	(25)	259.7 ± 11.14	237–280	(28)	257.3 ± 13.39
Width	9.4–11.6		10.16 ± 0.49	8.8–10.7		9.80 ± 0.55
Femur						
Length	100.9–121.5	(26)	108.78 ± 5.96	95.5–113.1	(34)	104.67 ± 4.97
Width	9.3–11.6		10.46 ± 0.82	9.2–11.5		10.20 ± 0.68
Tibiotarsus						
Length	185–218	(24)	197.87 ± 9.97	183–210	(32)	195.5 ± 8.58
Width	7.5–9.0		7.96–0.42	7.0–9.1		8.12 ± 0.49
Tarsometatarsus						
Length	110.2–129.3	(20)	118.18 ± 5.99	98.6–118.6	(23)	108.76 ± 6.32
Width	7.7–8.8		8.24 ± 0.37	7.4–9.0		8.40 ± 0.51

Note. Definitions of measurements are given elsewhere (Northcote 1979, 1980).

relation to the tarsometatarsus (for example, middle toe: tarsometatarsus for a Whooper Swan specimen was 128 mm:118 mm; for a Mute Swan specimen it was 139 mm:109 mm), both of which factors would conduce to more elegant movements on land. In addition, there are morphological differences in the form of the tarsal joint and the tarsometatarsus. The precalcaneal knob on the head of the tarsometatarsus moves in the intercondylar fossa of the tibiotarsus. Compared to Mute Swans, Whooper Swans have a more attenuated knob (Plate 1, b) and a narrower intercondylar fossa (the internal condyle is wider) (Plate 1, a); lateral movement of the tarsus is therefore more restricted and walking is more efficient. Flexor tendons of the toes run behind the tarsal joint and are held in place by ridges and grooves on the posteriorly projecting hypotarsus at the proximal end of the tarsometatarsus. Compared to those of Mute Swans, all 3 grooves in Whooper Swans are more nearly parallel to one another and to the long axis of the bone (Plate 1, d), so that the flexor tendons pull the toes in a direction more nearly parallel to the midline of the body and this again facilitates walking. Larger cranio-caudal depth of the middle trochlea of the Whooper Swan's tarsometatarsus (Whooper, 16.85 mm$\pm$0.845, n=13; Mute, 15.40 mm$\pm$0.526, n=12; P=0.0005) allows the corresponding toe to move in the greater arc that is required for taking a longer stride, while greater width across the trochleae (Whooper, 28.16 mm$\pm$1.417, n=12; Mute, 24.16 mm$\pm$1.987, n=9; P<0.0005) may provide more stability when the bird is standing on one foot whilst taking the stride. In Mute Swans the internal hypotarsal ridge extends posteriorly more than it does in Whooper Swans (Plate 1, c, e). Such modification may be correlated with the presence of relatively larger swimming muscles (Owre 1967).

The humerus in Whooper Swans is shorter than that in Mute Swans (Table 1) (P<0.0005) and is also stouter (for the mean ratio of width to length P<0.0005). The humerus being the only pneumatised limb bone in swans (Shufeldt 1909), greater stoutness may therefore be related to greater pneumaticity in Whooper Swans. (The volume of the pneumatic space in a 297 mm long Whooper humerus was 54 cc, that in a 304 mm long Mute Swan humerus was 44 cc.) The stouter humerus in Whooper Swans is able to withstand greater bending stresses and in conjunction with their greater wing length (Scott *et al.* 1972, Cramp & Simmons 1977) it may be an adaptation to migration at high altitudes.

These differences, besides showing a relation between form and function, may be useful taxonomically. The morphological characters may also be of help for determining the affinities of an extinct species.

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